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Convergence of $\mathcal{S}'$-Processes and Langevin Equations for $\mathcal{S}'$-Gaussian Processes

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Let (X_n) be a tight sequence of processes in $D([0, T], \mathcal{S}'(R^d))$. It is shown that weak convergence of (X_n) is equivalent to weak convergence of $(\tilde{X}_n)$ in $\mathcal{S}'(R^{d+1})$, where, given $x \in D([0, T], \mathcal{S}'(R^d))$, $\tilde{x} \in \mathcal{S}'(R^{d+1})$ is defined by $\langle \tilde{x}, \Phi \rangle = \int_0^T \langle x(t), \Phi(\cdot, t) \rangle \, dt$, $\Phi \in \mathcal{S}(R^{d+1})$. An analogous result holds for $[0, \infty)$.

Given a continuous Gaussian $\mathcal{S}'(R^d)$-valued process X, it is shown that if its covariance functional satisfies a certain condition, which can be expressed in terms of $\tilde{X}$, then X obeys a generalized Langevin equation whose form is obtained explicitly in terms of the covariance of X.

These results are illustrated with several examples of fluctuation limits of infinite particle systems, including Ito's model of an infinite system of Brownian motions (Math. Zeit. 182 (1983)), some models of infinite particle branching Brownian motions with immigration under several different scalings, and the voter model with hydrodynamic scaling.

Weak Convergence of a Sequence of Stochastic Difference Equations to a Stochastic Ordinary Differential Equation

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We consider a sequence of discrete parameter stochastic processes (called driven processes) X_k^ε defined by solutions to stochastic difference equations whose coefficients are autocorrelated stochastic processes (called driving processes) Y_k^ε,

$$X_{k+1}^\varepsilon - X_k^\varepsilon = F_\varepsilon(X_k^\varepsilon, Y_k^\varepsilon(\omega)).$$

Our interest is a classification of limit processes of driven processes by the degree of autocorrelation of driving processes. This type of problem is arising from population biology as continuous time approximations for discrete time models in random environments. For autocorrelated driving processes, we adopt uniform mixing processes, and the degree of autocorrelation is given by the mixing rate. It has been proved that limit processes are diffusion processes in the case of weak autocorrelation. On the other hand, if we consider deterministic (non-random) driving processes as the extreme case of strong autocorrelation, then limits are solutions to ordinary differential equations corresponding to deterministic difference equations. This consideration suggests that limit processes are solutions to stochastic ordinary differential equations (differential equations with random parameters),

$$\frac{\mathrm{d}x(t)}{\mathrm{d}t}=F(x(t),y(t,\omega)),$$

in the case of strong autocorrelation. Here, we obtain a limit theorem of weak convergence to stochastic ordinary differential equations under strong autocorrelation.

Limits for Stochastic Partial Differential Equations

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Consider a sequence of stochastic partial differential equations:

$$\frac{\partial}{\partial t}u^n(t,x)=L_t u^n(t,x)+\sum_i b_n^i(t,x,\omega)\frac{\partial}{\partial x_i}u^n(t,x)+c_n(t,x,\omega)u^n(t,x),$$

$$u^n(0,x)=f(x),$$

where L_t is an elliptic differential operator and b^n, c^n are random fields. Under appropriate conditions on the sequences $b_n, c_n, n\geq 1$, we show that the sequence of solutions $u^n(t,x)$ converges weakly to $u(t,x)$, which satisfies the equation

$$d_t u(t,x)=L_t u(t,x)\,\mathrm{d}t+\sum_i X^i(x,\circ\,\mathrm{d}t)\frac{\partial}{\partial x_i}u(t,x)+Y(x,\circ\,\mathrm{d}t)u(t,x),$$

where $X(x,t)$ and $Y(x,t)$ are random fields such that for each fixed x, these are Brownian motions, and $X^i(x,\circ\,\mathrm{d}t)$ denotes the Stratonovich stochastic integral. The treatment is based on the limit theorems for stochastic flows of diffeomorphisms.

Limit Theorems for a Class of Stochastic Flows and their Applications

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Consider the following system of SDE's: for $0\leq s\leq t$,

$$\begin{aligned}\mathrm{d}x^\varepsilon(t)&=\varepsilon^{-1}F(x^\varepsilon(t),y^\varepsilon(t))\,\mathrm{d}t+\sigma(x^\varepsilon(t),y^\varepsilon(t))\,\mathrm{d}B(t)\\ \mathrm{d}y^\varepsilon(t)&=\varepsilon^{-2}G(y^\varepsilon(t))\,\mathrm{d}t+\varepsilon^{-1}\gamma(y^\varepsilon(t))\,\mathrm{d}\beta(t)\end{aligned}\tag{1}$$

with the initial condition $x^\varepsilon(s)=x\in R^d$ and $y^\varepsilon(s)=y\in R^n$. Here $\{B(t), t\geq 0\}$ and $\{\beta(t), t\geq 0\}$ are standard Brownian motions with $E[B^p(u)\beta^q(v)]=\min(u,v)b_{pq}$. Then the R^d-component $x_y^\varepsilon(s,t;x)$ of the solution of (1) converges in law to some diffusion process under suitable assumptions (see [1]). Furthermore, for fixed $y\in R^n$,